



## Case report

# Death by complete decapitation of motorcyclist wearing full face helmet: Case report

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## ABSTRACT

We describe a case of complete decapitation following a motorcycle accident in which the victim was wearing a full face helmet. A young man lost control of his motorcycle and was thrown about 20 m, hitting his head against the barrier separating a tramline from the road. The resulting trauma caused his decapitation, the only fatal wound ascertained by the various forensic investigations. The authors present this rare case and compare it against the other two cases reported in the literature, providing some observations on the ways in which this injury can come about. The absence of abrasions or signs that the wound edges came into contact with a metal structure, the presence of signs of impact on the side of the helmet and the finding of a transversal fracture at the base of the skull point to the violent action of a side-to-side opposite force, due to the resistance provided by the lower edge of the protective helmet.

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## 1. Introduction

The use of a protective helmet when riding motorcycles is now a legal requirement throughout the Western world. Scientific and forensic research provides ample evidence of its efficacy in protecting the head in the event of road injury. In Italy, article 33 of Law no. 472 of 7 December 1999 requires its use by all moped and motorcycle riders and passengers of all ages. The law permits the use of three main types of helmet: the half helmet (considered to provide the least protection), the intermediate grade, open face helmet and the full face helmet, considered the safest, which covers the face and head on all sides, including a mobile visor over the eyes [1]. In Italian legislation, all types of helmet require type-approval by the Ministry of Transport in application of ECE legislation, which requires three identifying numbers to be reported on the inside of the helmet (State of registration, type-approval and manufacturing number) [2]. As noted above, this safety device has been found to have a significant effect in reducing the severity of head injuries and the number of deaths in the users of two-wheeled vehicles [3].

Full face helmets in particular significantly reduce the morbidity of head, brain and facial injuries [4]; however, their efficacy may be

limited [5] in the event of high-speed impact with the road surface. These cases can present cranial fractures, mainly in the temporoparietal region [6] and the basicranium [5], involving the foramen magnum, as well as cervical injuries [6]. Obviously, the helmet provides no protection to other body areas, such as the torso [7]. Fatal injuries such as complete traumatic decapitation are very rarely reported in the forensic literature [8,9], although a large number of cases of incomplete decapitation of motorcyclists [4,10] and car occupants [9,11] have been reported. In all these cases, the midsection (C3–C5) of the cervical spine, an area not protected by the helmet, has been found in international case studies [12] to be the area most vulnerable to traumatic fracture. The suggested mechanism of injury is therefore a direct blunt trauma strong enough to cause the head to be detached after its impact with a fixed obstacle; however a direct injury to the cervical spine is also a possible mechanism of injury. This can be deduced from an analysis of the features of the obstacles responsible for fatal injuries found at the scene of the road accident, such as a metal barrier at the side of the road [11], temporarily parked vehicles (lorry tailgate) [6] or objects temporarily found at the traffic injury site (side of a car [8], chain for road closure [9]); the features of the described cervical injuries (significant abrasion at the edges of the cervical injury) can also suggest this mechanism.

## 2. Case report

This case involved a 29-year-old motorcyclist, wearing a full face helmet, who began a race against the rider of a high-powered

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scooter one night on a city street in Milan. Witnesses saw him lose control of his bike at high speed during the race. The front wheel of the vehicle struck the curb of the road, so he was thrown about 20 m on the opposite side of the street, and his head, protected by the helmet, hit a steel barrier separating the road from a tram line. At this point the traumatic separation of his head from his body was observed. The other biker had lagged behind and so he managed to avoid consequences for himself. Once the police had finished their work at the scene the body was taken to the Institute of Forensic Medicine for the necessary judicial investigations. The victim's family were asked to identify the body, at which time they reported that the victim, a car and bike enthusiast, did not suffer from any illness, did not take any medicines, drugs or alcohol, smoked about 20 cigarettes a day and worked as a mechanic.

### 3. Materials and methods

After the time required to view the documentation and after the acquisition of the technical elements of the case, the Judicial Authority required autopsy twelve days after death of the man, who reached the mortuary table with his head separated from his body (Fig. 1). The body was well preserved and weighed 69 kg, with a length of 179 cm.

There were scant signs of hypostasis in the dependent areas of the prone body. The head, still enclosed in the full face helmet, was carefully examined. The helmet bore an obvious blackish streak, 4 cm × 10 cm, on the right side, corresponding to the point of impact with the metal barrier on the street. There were no traumatic injuries to the scalp or face, with the exception of an abraded area between the chin and the hyoid bone. The head had been separated from the body at the C4–C5 cervical tract. On dissection, the deep surface of the scalp revealed the infiltration of blood in the right temporoparietal area, with no other traumatic findings. The dura mater was unharmed and the epidural and subdural spaces clear. There was slight subarachnoid bleeding in the right temporoparietal area, while no local trauma was observed to the brain, cerebellum or brainstem. The cranial vault was undamaged while there was a semicircular fracture at the base of the skull extending to the two temporo-occipital joints, involving both pars petrosa and, anteriorly, the sella turcica. Examination of the remaining body areas revealed numerous abrasions on the upper and lower limbs and fracture of the C4–C5 intervertebral disc, with full thickness interruption of the spinal cord and intense infiltration of blood in the subcutaneous soft tissues around the injury (Fig. 2); examination of the skin around the decapitation points of both the head and trunk did not reveal any signs of abrasion. Finally, avulsion of the nasopharynx from the skull with bilateral damage to the cervical neurovascular fascia was observed, while the oesophagus and trachea were undamaged. There were no other significant findings on examination of the chest and abdominal organs: specifically, there were no signs of blood aspiration. Organ, brain and body fluid samples were taken for subsequent histological and toxicological analysis.

### 4. Results

Toxicological examinations were carried out on samples of cardiac blood, peripheral blood, urine and bile. All tested negative for alcohol and narcotics. The investigations were completed with



Fig. 1. Macroscopic view of traumatic head separation with full thickness interruption of the C4–C5 cervical tract and complete resection of the spinal cord.



Fig. 2. Detail of section of the head separation where the injury edges appear generally irregular and infiltrated with blood; signs of abrasion under the chin.

histopathological examination of the organs and wound edges, using standard post-fixation, basic haematoxylin-eosin staining and specific histochemical staining (Masson's trichrome stain for connective tissue and Perl's stain for the detection of blood iron as an index of tissue infiltration by vital blood). Preparations of samples from the brain and other organs did not reveal any significant findings beyond what had already been seen in the autopsy. Optical microscopic examination confirmed the presence of intense acute blood infiltration in the skin margins of the injury and in the C4–C5 paravertebral soft tissues, with morphologically intact red blood cells in the absence of granulocytes. There were no significant findings from histological examination of the margins of the cervical injury. In conclusion, the cause of death was found to be blunt head trauma causing complete decapitation following a single vehicle (motorcycle) injury against a fixed obstacle.

### 5. Discussion

Examination of the literature reveals that most deaths by decapitation are the result of self-harm, but even in suicides [13], it is a rare event (<1%) [14]. The few literature reports describe complete [15] or incomplete [16] decapitation in cases of hanging, especially if preceded by a fall, or of suicide by train [6,17,18]. There have also been rare cases due to injuries while driving agricultural vehicles [19] or involving the occupants of high-speed vehicles [20], accounting for less than 0.01% of all traffic injury [21].

There is unambiguous statistical evidence that due to the limitations of the protective devices, the riders and passengers of two-wheeled vehicles are at greater risk of injuries resulting from a traffic accident than the occupants of closed vehicles [22], and although in Western countries there are far fewer registered motorcycles and mopeds than cars, the rate of severe injuries and deaths among motorcyclists is far higher than that for car drivers

[23]. This can be explained by the severity of the injuries resulting from the motorcyclist's inevitable impact with the ground following a road injury [6]. This phase, after the crash, is a common cause of fatal injury: such injuries are sometimes to the head, but very rarely, in special cases, they involve complete decapitation, especially if a full face helmet is used [8,9]. In these cases the spinal column, which is not completely protected by the helmet, can be vulnerable to angular acceleration. This can cause severe cervical injuries such as incomplete resection of the head, which cannot be prevented by the use of this safety device [24]. In reports of these cases, the mechanism producing the fatal injury is indicated as hyper-extension of the neck induced by violent facial impact [25], with transmission of the force to the cervical spine between C3 and C5. The other extreme injury – complete decapitation, which is rare in injury involving motorcyclists wearing a full face helmet – is usually attributed to a violent direct blow to the central area of the neck [8,9]. However, analysis of the case in question suggests another possible mechanism for this injury. In fact, the absence of any abrasion to the skin margins of the cervical injury or of any findings attributable to direct impact with some part of the metallic structure, together with the presence on the side of the victim's helmet of clear signs of impact against the barrier, lead to the conclusion that violent trauma to a head protected by a full face helmet can also cause an extremely strong opposite force on the neck area corresponding with the lower edge of the helmet: this action is strong enough to cause the complete amputation of the cervical tract through a side to side directional force, causing tissue avulsion in the front part of the neck not corresponding with the edge of the helmet and the victim's complete decapitation and death. Clearly, this mechanism can be proposed only for extremely violent impacts. It should not be forgotten that in the case in question, even in the presence of adequate protection there was a transversal fracture at the base of the skull and leptomeningeal haemorrhage, fully consistent with the application of an extremely strong blunt force in a side-to-side direction from right to left. This finding also fits in with the unambiguous interpretation of the results of the forensic examination.

## 6. Conclusions

We described a rare case of death by complete decapitation of a young motorcyclist wearing a full face helmet. Even if correctly worn, this device does not protect the neck.

On the basis of the rare literature discussions of this event, this area can be affected by severe direct trauma, causing complete decapitation, due to the violence of the impact of the neck area against a fixed, generally narrow obstacle. The evidence from the forensic investigations of the case presented herein suggests that decapitation can also occur through another mechanism: a violent blow against the side of the protective helmet produces an opposite, side-to-side force on the neck area due to the resistance provided by the lower edge of the helmet. This is consistent with the absence of any abrasion of the skin margins around the decapitation injury, the lack of any signs of contact with a metal structure in this area and the presence of a transversal fracture at the base of the cranium.

The remaining head and brain structures were free of any injury, with the exception of abrasions under the chin, widely reported in cases involving use of a helmet and attributable to the local action of the buckle fastening system. The conclusions permitted by the data obtained in this rare case should be considered both during the forensic study of autopsy findings from similar cases and in the interpretation of analogous cases where reconstruction of the events and attribution of responsibility are required.

## References

- [1] B.C. Liu, R. Ivers, R. Norton, S. Boufous, S. Blows, S.K. Lo, Helmets for preventing injury in motorcycle riders, *Cochrane Database Syst. Rev.* 23 (1) (2008), CD004333.
- [2] Regolamento ECE/ONU n. 22/05. Agreement concerning the adoption of uniform technical prescriptions for wheeled vehicles, equipment and parts which can be fitted and/or be used on wheeled vehicles and the conditions for reciprocal recognition of approvals granted on the basis of these prescriptions.
- [3] V.G. Wagle, C. Perkins, A. Vallera, Is helmet use beneficial to motorcyclist? *J. Trauma* 34 (1) (1993) 120–122.
- [4] A. Oliva, K. Vernooy, R. Cooter, D.J. David, V. Pascali, Helmet-induced neck degloving in a motorcyclist, *J. Trauma* 58 (2) (2005) 370–371.
- [5] R.D. Cooter, D.J. David, A.J. McLean, D.A. Simpson, Helmet-induced skull base fracture in a motorcyclist, *Lancet* 1 (8577) (1988) 84–85.
- [6] P. Saukko, B. Knight, *Knight's: Forensic Pathology*, third ed., London, pp. 290–291, 2004.
- [7] H.J. Hoekstra, L.M. Kingma, Bilateral first rib fractures induced by integral crash helmets, *J. Trauma* 25 (1985) 566–567.
- [8] I.D. Doichinov, S.S. Spasov, T.S. Dobrev, J.A. Doichinova, Complete decapitation of a motorcyclist in a road accident. A case report, *Folia Med. (Plovdiv)* 49 (3–4) (2007) 80–83.
- [9] Y. Ihama, T. Miyazaki, C. Fuke, H. Niki, T. Maehira, Complete decapitation of a motorcycle due to roadblock chain, *Int. J. Legal Med.* 122 (6) (2008) 511–515 (Epub 2008 Sep 16).
- [10] M. Hitosugi, K. Fukui, A. Takatsu, Incomplete decapitation of a motorcyclist from hyperextension by inertia: a case report, *Med. Sci. Law* 41 (2) (2001) 174–177.
- [11] R. Rautji, A. Rudra, V. Dixit, D.N. Bhardwaj, T.D. Dogra, Decapitation in road traffic accident—a case report, *Forensic Sci. Int.* 135 (2003) 237–238.
- [12] A.C. Aufderheide, C. Rodriguez-Martin, *The Cambridge Encyclopedia of Human Paleopathology*, vol. 29, Cambridge University Press, 2006.
- [13] M. Tsokos, E.E. Türk, S. Uchigasaki, K. Püschel, Pathologic features of suicidal complete decapitations, *Forensic Sci. Int.* 139 (2–3) (2004) 95–102.
- [14] R.W. Byard, J. Gilbert, R. James, J. Lipsett, Pathological features of farm and tractor-related fatalities in children, *Am. J. Forensic Med. Pathol.* 20 (1999) 73–77.
- [15] F. Dedouit, G. Tournel, A. Bécart, V. Hédouin, D. Gosset, Suicidal hanging resulting in complete decapitation—forensic, radiological, and anthropological studies: a case report, *J. Forensic Sci.* 52 (5) (2007) 1190–1193 (Epub 2007 Jul 23).
- [16] K. Tóro, I. Kristóf, E. Keller, Incomplete decapitation in suicidal hanging—report of a case and review of the literature, *J. Forensic Leg. Med.* 15 (3) (2008) 180–184 (Epub 2007 Sep 5).
- [17] A. Battistini, G. Gentile, E. Palazzo, R. Zoja, Train-related suicides in Milan, Italy: analysis of cases 1993–2008, *Med. Sci. Law* 49 (3) (2009) 185–190.
- [18] R. Zoja, A. Battistini, G. Gentile, Death with complete decapitation: report of four suicides by train, *Am. J. Forensic Med. Pathol.* 30 (3) (2009) 303–306.
- [19] S. Demirci, K.H. Dogan, Z. Erkol, G. Gunaydin, Accidental decapitation: a case report, *Am. J. Forensic Med. Pathol.* 30 (3) (2009) 270–272.
- [20] H. Nadjem, D. Ropohl, Complete transection of the trunk of passengers in car accidents, *Am. J. Forensic Med. Pathol.* 17 (1996) 167–171.
- [21] R.W. Byard, J.D. Gilbert, Characteristic features of deaths due to decapitation, *Am. J. Forensic Med. Pathol.* 25 (2004) 129–130.
- [22] B.L. Bachulis, W. Sangster, G.W. Gorrell, W.B. Long, Patterns of injury in helmeted and nonhelmeted motorcyclists, *Am. J. Surg.* 155 (5) (1988) 708–711.
- [23] M. Hitosugi, A. Takatsu, A. Shigeta, Injuries of motorcyclists and bicyclists examined at autopsy, *Am. J. Forensic Med. Pathol.* 20 (1999) 251–255.
- [24] M. Hitosugi, A. Shigeta, A. Takatsu, A.T. Yokoyama, S. Tokudome, Analysis of fatal injuries to motorcyclist by helmet type, *Am. J. Forensic Med. Pathol.* 25 (2) (2004) 125–128.
- [25] M. Hitosugi, Y. Motozawa, T. Nagai, S. Tokudome, Decapitation in helmeted motorcyclist, *Am. J. Forensic Med. Pathol.* 26 (2) (2005) 198 (Letters to Editor).